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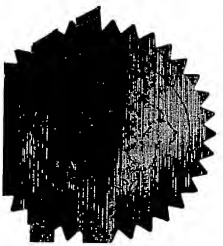

Signed A W Brewer

Dated 16 April 2004

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P01/7700 0.00-0307429.1

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Request for grant of a patent

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1. Your reference
   5459901/PT

2. Patent Application Number
   0307429.1
   31 MAR 2003

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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   202 West Block
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   London
   SE1 7GL

   Patents ADP number *(if known)* 8600835001

   If the applicant is a corporate body, give the country/state of its incorporation
   Country: GB
   State:

4. Title of the invention

   Bicycle Hub Gear

5. Name of agent

   "Address for Service" in the United Kingdom to which all correspondence should be sent

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   Patents ADP number 18260001

6. Priority details

Country	Priority application number	Date of filing

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7. If this application is divided or otherwise derived from an earlier UK application give details

Number of earlier application | Date of filing

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TOPLEY; Paul

Tel: 020 7831 2290

5459901

BICYCLE HUB GEAR

The present invention relates to bicycles, and is particularly concerned with bicycles having a planetary gear-change mechanism contained in the hub of the driven wheel.

Hub mounted gearboxes are well known in the bicycle art, and are conventionally based on the widely understood, planetary gearbox principle. Planetary-geared hubs for bicycles having two, three, four, five, seven, eight, and even fourteen speed ratios are currently available commercially.

In a conventional three-speed hub-mounted gearbox, a central spindle is provided which is rigidly attachable at both its ends to the bicycle frame. A sun gear is non-rotatably mounted to the spindle, and engages planet gears mounted in a planet carrier rotatably carried by the spindle. A drive sprocket, to engage the bicycle chain, rotates coaxially with the spindle.

An annulus gear is engaged with the planet gears, and is movable to engage and rotate with either the drive sprocket or with the outer casing of the hub, to which the spokes of the wheel are attached. The planet carrier is likewise movable to engage and rotate with either the drive sprocket or the hub.

In the "low" gear position, the drive sprocket and annulus rotate together, and the planet carrier rotates with the hub, so that the wheel rotates more slowly than the drive sprocket.

In the "middle" gear position, the drive sprocket engages the annulus and the hub likewise engages the annulus, so that the wheel rotates at the same speed as the drive sprocket.

In the "high" gear position, the drive sprocket engages the planet carrier and the annulus engages the hub, so that the wheel rotates faster than the drive sprocket.

The present invention does not concern the inner workings of the hub gearbox, beyond the considerations that the bicycle wheel is mounted to the outer casing of the gearbox, and the central spindle must be held against rotation relative to the bicycle frame in order to transmit torque from the drive sprocket to the outer casing of the gearbox and thence to the wheel.

The main advantage of a planetary-geared hub is that the gears are compactly sealed within the hub outer casing. Because the gears are protected from water and debris, planetary-geared hubs require low maintenance.

Another advantage is that there is no requirement for a rear derailleur mechanism to shift gears. This simplifies the bicycle chain drive because the chain path does not move relative to the bicycle frame as the rider changes gear, as is the case with conventional multi-sprocket derailleur arrangements. Since there is a fixed chain path, a chain cover can be fitted to the bicycle to further protect the bicycle chain drive from dirt. This chain cover also protects the rider's leg or clothing from soiling by chain lubricants.

There are, however, drawbacks to the current state of the art in planetary-geared hubs. Because planetary-geared hubs are designed to be mounted to the bicycle frame on both sides of the rear bicycle wheel, then in order to remove the tyre from the wheel, for example if the tyre is punctured, the entire rear wheel - including the planetary-geared hub - must be removed from the bicycle in order to repair the flat tyre. This can be extremely time consuming.

If the bicycle has been fitted with a rear chain drive cover, even more time is required to remove the rear wheel. First the cover must be removed, and then the planetary-geared hub axle nuts must be loosened. The bicycle drive chain can then be removed and consequently, the planetary-geared hub, including the rear bicycle wheel, can be removed and the tyre can then be repaired.

Another drawback to current planetary-geared hubs is that if the rear wheel needs to be removed for transporting the bicycle in a car or for storing the bicycle in a compact space, the same time-consuming procedure must be followed.

One way of reducing the time required to remove the rear bicycle tyre would be to mount the planetary-geared hub to the bicycle frame on only one side of the rear bicycle wheel. A cantilever bicycle frame designed to suit this one sided mounting would allow the tyre to be removed without the need to remove the planetary geared hub and wheel from the bicycle frame.

However, central axles on current planetary-geared hubs are not designed to allow mounting of the planetary-geared hub only on one side. The diameter of the central axle is too small to support one-sided mounting. If mounted in this way - under normal use - the central axle will bend and then break due to the weight of the bicycle and rider.

If the central axle or spindle is increased in diameter to strengthen the axle, then the diameter of the sun gear is likewise increased and the consequent increases in diameter of the planet gears and annulus required to preserve operable gear ratios will result in a hub which is large in diameter, heavy and unwieldy, and requires

shortened spokes to fit it to a standard diameter wheel rim.

An object of this invention is to provide a planetary-geared hub which can be mounted to a bicycle frame such that removal of the rear bicycle tyre does not require removal of the planetary-geared hub from the bicycle frame.

A further object is to provide a bicycle having a hub-mounted gearbox, and a frame structure affording substantially unobstructed access to one side of the rear wheel.

A further objective of the invention is to provide a hub-mounted planetary gearbox which can be supported by a bicycle frame intermediate its axial length and at only one of its axial ends, and wherein a bicycle wheel is removably attachable to the gearbox at the other axial end thereof.

One aspect of the present invention provides a bicycle having front and rear wheels mounted to a frame, wherein the rear wheel is mounted to the frame at one side of the wheel only, and wherein the rear wheel comprises a hub-mounted planetary gearbox. In one embodiment the rear wheel is supported at the end of a cantilever arm, but it is foreseen that a bicycle frame may be produced

wherein the rear wheel is supported on one side by a triangulated frame.

The bicycle frame may incorporate rear suspension by pivotally mounting the front end of a single rear swinging arm to the bicycle frame and mounting the wheel to the rear end of the swinging arm. In this case a spring and damper assembly will be provided, acting between the swinging arm and the frame.

A second aspect of the invention provides a frame for a bicycle, to which a rear wheel having a hub gearbox may be mounted with one side of the wheel unobstructed by frame elements. In one embodiment the frame comprises a single rear arm, to the rear end of which the rear wheel is mountable, with the wheel positioned to one side of the rear arm.

A further aspect of the invention provides a hub for a bicycle wheel comprising a generally cylindrical casing for a planetary gearbox, the casing being adapted to receive an external bearing intermediate the axial extent of the casing for mounting the hub to a bicycle frame. The hub may further comprise mounting elements such as a pair of spaced external flanges for attachment of spokes to form a bicycle wheel, or the hub may be attachable to a cast or moulded wheel.

A yet further aspect of the invention provides a hub-mountable planetary gearbox for a bicycle, comprising a central spindle attachable at one end to a bicycle frame, and an axisymmetric outer casing having a circumferential bearing surface intermediate its axial extent, the bearing surface being engageable with a supporting bearing for mounting the gearbox to a bicycle frame. A pair of spaced bearing surfaces may be provided instead of a single bearing surface.

A yet further aspect provides a combination of a planetary gearbox with an external mounting bearing fitted thereto intermediate the axial length of the gearbox casing.

The gearbox may be provided, at its axial end remote from said one end, with means to attach a bicycle wheel to the gearbox casing, and most preferably the bearing surface is positioned to be substantially central, in the axial direction, relative to the wheel in its mounted position.

Preferably the outer hub casing is made of steel or aluminium similar to current planetary-geared hub outer casings. The rotatable bearing may be of the ball, roller, or tapered roller type. The means for attaching a bicycle wheel may be flanges to accept traditional bicycle spokes, or the hub casing may be cooperable with

a mating bicycle wheel hub for a cast metal or fibre reinforced composite bicycle wheel.

Exemplary embodiments of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a rigid-frame bicycle incorporating the hub gear;

Figure 2 is a perspective view of a full-suspension bicycle incorporating the hub gear;

Figure 3 is a cutaway perspective view of the rear arm and hub gear;

Figure 4 is a perspective view of the hub gear housingand supporting bearing of Figure 3;

Figure 5 is a perspective view of the hub gearbox, supporting bearing, drive sprocket and housing;

Figure 6 is a perspective view of the hub gearbox housing, showing an alternative arrangement for attaching a bicycle wheel;

Figure 7 is a view similar to Figure 6, illustraing a second alternative attachment arrangement;

Figure 8 is a view similar to Figures 6 and 7, illustrating a third attachment arrangement; and

Figures 9 and 10 are sectional and perspective views, respectively, showing a fourth wheel attachment arrangement.

Referring now to the drawings, Figure 1 shows a rigid-frame bicycle 1, having both its front 2 and rear 3 wheels mounted to the frame 4 at only one end of their respective axles.

The bicycle frame 4 comprises a rigid lower tube 5, to the approximate centre of which the pedals 6 are mounted. The forward end of the lower tube 5 incorporates a steering tube 7, to which the front fork assembly 8 and the handlebars 9 and handlebar stem 10 are mounted for rotation as a single unit.

Extending upwardly from the approximate centre of the lower tube 5 is the saddle stem 11, to the top of which the saddle 12 is mounted.

The part of the lower tube 5 extending rearwardly from the pedals 6 constitutes a rear arm 13, to one side of which the rear wheel 3 is mounted. The frame 4 is so arranged that the plane of the rear wheel 3 passes through the steering tube 7 and through the centre of the

saddle 12. The rear arm 13 may be laterally offset from the forward part of the lower tube 5 to achieve this geometrical arrangement.

An optional reinforcing strut 4a may extend from the rear arm 13 to the saddle stem 11, to reduce stresses at the forward end of the rear arm 13.

Figure 2 is a view similar to Figure 1, showing a bicycle having rear suspension. In this embodiment, the rear arm 13 is pivotally mounted at its forward end to the lower tube 5 of the frame 4. A spring and damper assembly 14 extends between the rear arm 13 and the lower part of the saddle stem 11. In other respects, the frame 4 is similar to that described in relation to Figure 1.

The rear wheel 3 is mounted to the rear arm 13 in a similar manner in both of the arrangements shown in Figures 1 and 2. Figure 3 is a cut-away perspective view of the rear arm 13 and rear wheel 3, to show the hub-mounted gearbox arrangement.

Referring now to Figure 3, the rear arm 13 is tubular in form, and the pedals 6 are mounted to a pedal spindle supported in bearings in the rear arm 13. A chain sprocket is mounted to the pedal spindle to rotate with the pedals, and a chain 15 passes round this sprocket and

round a drive sprocket 16 associated with a hub-mounted gearbox 17.

As stated above, the inner workings of the hub-mounted gearbox are not relevant to the present invention, in that the number of speed ratios provided by the gearbox and the means in which gear selection is effected may be entirely conventional. The hub gearbox 17 includes a central spindle 18 and an outer casing 19. The outer casing 19 has a pair of spaced external flanges 20 and 21 to receive spokes 22 connecting the hub to the rim 23 of the rear wheel 3. The outer casing 19 comprises an inner cylindrical shell 24 which surrounds the transmission components of the gearbox, and an outer shell 25 to which the flanges 20 and 21 are mounted. An annular space 26 between the inner and outer shells 24 and 25 accommodates a bearing 27, preferably arranged to be positioned centrally between the flanges 20 and 21 in the direction of the wheel axis 28.

The rear arm 13 has a lateral tubular extension 29, open at its end to closely receive the bearing 27. The rear wheel 3 is thus mounted to the arm 13 by means of the bearing 27, which supports the outer casing 19 of the hub gearbox 17. The arm 13 is provided with a bore through which the central spindle 18 of the hub gearbox 17 can extend, the central spindle 18 being secured to the rear arm 13 by a clamping nut 30. The clamping nut 30 may

serve to immobilise the central spindle 18 relative to the rear arm 13, or alternatively the central spindle 18 may have a non-circular cross-section which is received in a complementary opening in the rear arm 13 to prevent relative rotation of the spindle 18 and the rear arm 13 about the rear wheel axis 28.

Figure 4 shows, to an enlarged scale, the outer casing 19 and the bearing 27 of the assembly shown in Figure 3. The transmission components of the hub gearbox and the rear arm 13, are omitted for clarity. Figure 5 is a view similar to Figure 4, showing the transmission components of the hub gearbox 17 in schematic form, the drive sprocket 16 and the central spindle 18. The bearing 27 is shown in position on the inner shell 24 of the outer casing 19 of the hub gear box 17. As can be clearly seen in Figure 5, the central spindle 18 is formed with a flat 18a to give the central spindle a non-circular cross-section. The central spindle 18 in this embodiment will be received in a "D" shaped opening in the rear arm 13, in order to prevent any rotation of the central spindle 18 about the rear wheel axis 28 relative to the rear arm 13. This ensures that the sun gear of the planetary hub gear box remains fixed, and torque can be transmitted through the gearbox from the drive sprocket 16 to the outer casing 19. Two or more flats 18a may be formed on the spindle 18, or the spindle may have a polygonal cross-section. The opening in the rear arm 13 will be

shaped to receive the spindle 18 but to prevent rotation of the spindle in the opening.

The preferred location of bearing 27 is such that rotatable bearing 27 lies in the central plane of rear wheel 3. With this preferred location, forces acting substantially perpendicular to the axis of rotation 28 of rear wheel 3 will be transferred to the rear arm 13 of bicycle frame 4 through outer hub casing 19 and rotatable bearing 27 thus substantially reducing or eliminating bending moment forces acting on central spindle 18.

It is however foreseen that the bearing 27 may be fitted externally to the lateral extension 29 of the rear arm 13, with the bearing supporting the outer shell 25 of the hub casing 19 directly by abutting the radially outer wall of the annular space 26. Furthermore, two or more bearings 27 may be mounted either internally in the extension 29 to engage the outer surface of the inner shell 24, or may be mounted externally of the extension 29 to engage the inner face of the outer shell 25.

In the previously-described embodiment, the flanges 20 and 21 and the outer shell 25 are integrally formed as part of the outer casing 19 of the hub gearbox 17. While the tyre may be removed from the wheel 3 without the need to dismount the wheel 3 from the rear arm 13, removal of

the wheel from the rear arm 13 requires removal of the gearbox 17 and disconnection of the chain 15 from the chain sprocket 16. There will now be described embodiments of the invention which provide for simple removal of the rear wheel 3 from the bicycle frame, without disturbing the hub gearbox 17 or its connection to the chain 15.

Figures 6 to 10 illustrate embodiments of the invention wherein the outer casing 19 of the hub gearbox 17 is provided with a mounting arrangement to which the wheel is removably attachable.

Figure 6 shows a first alternative arrangement for attaching a bicycle wheel to the hub gearbox. Outer hub casing 19 with rotatable bearing 27 has a threaded section 31 at its free end. Threaded section 31 cooperable with a mating threaded bore 32 in a bicycle wheel 33. This alternative means for attaching a bicycle wheel allows removal of the bicycle wheel by unscrewing mating threaded bicycle wheel 33 from outer hub casing 19. A locking arrangement such as a locknut (not shown) or an axially-extending locking pin such as that shown in Figure 8 may be provided on the threaded section 31 to secure the wheel against inadvertent loosening.

Figure 7 shows a second alternative arrangement for attaching the bicycle wheel to the hub gearbox. Outer

hub casing 19 with rotatable bearing 27 has a tapered section 34 at its free end and drive pins 35 extending axially from the end of tapered section 34. Tapered section 34 cooperates with a mating tapered bore 36 in a bicycle wheel 37. Drive pin holes 38 are provided in the bicycle wheel 37 to accept the drive pins 35 as the tapered bore 36 is placed over the tapered section 34 of the outer casing 19 of the hub gearbox 17. Drive pins 35 prevent bicycle wheel 37 from rotating independently of outer hub casing 19. A retaining means such as an axially extending locking pin such as that shown in Figure 8 may be provided to retain the wheel on the tapered section 34. Alternatively, pins 35 may be threaded to receive threaded nuts to retain the wheel.

Figure 8 shows a third alternative arrangement, in which outer hub casing 19 with rotatable bearing 27 has a splined section 38 at its free end. Splined section 38 is cooperable with a mating splined bore 39 in bicycle wheel 40. Splined section 38 cooperates with splined bore 39 to prevent bicycle wheel 40 from rotating independently of outer hub casing 19. Locking means, such as an axially extending threaded fastener 41 extending through a clearance hole 42 in the wheel 40 to engage a threaded bore 43 in the hub casing 19, may be provided to retain the wheel on the hub casing. The threaded fastener 41 may have a hand operable "butterfly"

head 44, or may be a tool-operated fastener such as a hexagon head, slotted head, or socket screw.

Figures 9 and 10 are sectional and perspective views, respectively, of a fourth alternative arrangement for mounting a bicycle wheel to the hub gearbox. In the arrangement shown, the outer casing 19 of the hub gearbox 17 is formed at its free end with a protruding cylindrical section 44 having a circumferential external groove 45. The bicycle wheel 46 is formed with a central bore 47 which closely engages the outer surface of the cylindrical section 44 of the hub. Adjacent the bore 47, the wheel 46 is provided with three threaded holes 48, through which threaded fasteners 49 extend. The threaded fasteners 49 have an enlarged head 50 at one end, to which an operating lever 51 is attached. The end of the fastener 49 remote from the head 50 protrudes beyond the threaded bore 48.

The operating levers 51 have a grip portion 52 at one end, and an engaging lobe 53 adjacent the head 50 of the fastener 49.

To mount the wheel to the hub gearbox, the wheel is offered up so that the protruding cylindrical section 44 enters the bore 47 of the wheel 46. The wheel is then aligned with the outer casing 19, so that the protruding

ends of the fasteners 49 enter clearance openings 54 in a flange 55 surrounding the base of the cylindrical protruding section 44 of the outer casing 19 of the gearbox. The operating levers 51 are then rotated by means of the gripping portions 52, so that the engagement lobes 53 of the levers 51 engage the circumferential groove 45. As the levers 51 are rotated with the engaging lobes 53 in the groove 45, the threaded engagement between the fasteners and the threaded bores 48 causes the wheel 46 to be clamped securely onto the flange 55, as the fasteners 49 are withdrawn from the threaded bores 48 with the engagement lobes 53 in contact with the wall of the groove 45.

In addition to the mounting arrangements described in the Figures, other arrangements for releasably mounting a wheel to the end of the outer casing 19 of the hub gearbox remote from the rear arm 13 are possible and are to be considered as included in the scope of the present application.

CLAIMS

1. A hub-mountable planetary gearbox for a bicycle, comprising an elongate central spindle attachable at one of its ends to a bicycle frame;

a drive sprocket rotatable about the central spindle and mounted adjacent said one end thereof; and

an outer casing rotatable coaxially with said central spindle and containing a planetary gear transmission for transmitting torque between said drive sprocket and said outer casing, the outer casing comprising means for mounting a wheel to the casing coaxially with the spindle;

wherein intermediate the axial length of the outer casing, there is provided an external bearing surface for engaging a supporting bearing for mounting the gearbox to a bicycle frame.

2. A planetary gearbox according to claim 1, wherein the central spindle has a non-circular cross-section.

3. A planetary gearbox according to claim 1 or claim 2, wherein the outer casing comprises coaxial outer and inner shells separated by an annular recess open towards said one end of said spindle, and wherein the bearing

surface is a radially-facing surface within the annular recess.

4. A gearbox according to claim 3, wherein the bearing surface is provided on a radially-outwardly facing surface of the recess.

5. A gearbox according to claim 3, wherein the bearing surface is provided on a radially-inwardly facing surface of the recess.

6. A gearbox according to any of claims 3 to 5, wherein the outer shell of the casing is formed with radially-outwardly extending spaced flanges for attaching spokes of a bicycle wheel.

7. A gearbox according to claim 6, wherein the bearing surface of the casing is positioned axially between the flanges of the outer shell.

8. A gearbox according to claim 1 or claim 2, wherein the outer casing has a mounting formation at its end remote from said one end of said spindle for detachably mounting a bicycle wheel to the casing.

9. A gearbox according to claim 8, wherein the mounting formation comprises a splined shaft coaxial with the spindle.

10. A gearbox according to claim 8, wherein the mounting formation comprises a conical projection coaxial with the spindle and tapering in a direction away from said one end of the spindle.

11. A gearbox according to claim 9 or claim 10, further including retaining means operable to retain a bicycle wheel mounted to the mounting formation against movement in the axial direction away from the mounting formation.

12. A gearbox according to claim 8, wherein the mounting formation comprises a screw-threaded region coaxial with the spindle.

13. A gearbox according to claim 8, wherein the mounting formation comprises a cylindrical extension of the casing extending away from said one end of the spindle, the cylindrical extension being formed with an external circumferential groove at its end remote from the casing.

14. A gearbox according to claim 12 or claim 13, wherein

the mounting formation includes locking means selectively operable to prevent relative rotation of the wheel and the outer casing of the gearbox.

15. A gearbox according to any preceding claim, wherein the outer casing is provided with two axially-spaced bearing surfaces.

16. A combination comprising a gearbox according to claim 1 and an annular supporting bearing mounted to the external bearing surface of the outer casing of the gearbox.

17. The combination of claim 16 wherein the bearing comprises inner and outer bearing parts and rolling elements interposed therebetween, the inner bearing part being mounted to the bearing surface of the outer casing of the gearbox.

18. The combination of claim 16 wherein the bearing comprises inner and outer bearing parts and rolling elements interposed therebetween, the outer bearing part being mounted to the bearing surface of the outer casing of the gearbox.

19. The combination according to any of claims 16 to 18, wherein the outer casing comprises a plurality of bearing surfaces, and a respective supporting bearing is engaged with each bearing surface.

20. A bicycle frame for use with the gearbox of claim 1, the bicycle frame comprising an elongate element provided at one of its ends with a transversely-extending tubular mounting portion having an annular bearing surface for engaging an annular bearing, the arm being further formed with an opening coaxial with the bearing surface, the arrangement being such that the central spindle of the planetary gearbox is engageable with said opening, and the bearing surfaces of the tubular mounting portion and the gearbox outer casing are engageable with an annular bearing assembly to mount the outer casing of the gearbox to the bicycle frame.

21. A rear swinging arm for a suspended bicycle frame, comprising an elongate element pivotally mountable at one end to a bicycle frame and having an attachment point intermediate the length of the arm for attaching suspension spring means, the swinging arm being formed at its other end with a transversely-extending tubular mounting portion and an opening substantially coaxial

with said tubular mounting portion, the tubular mounting portion being formed with a bearing surface for receiving an annular bearing engageable with the bearing surface of a gearbox according to claim 1, and the opening being engageable with said one end of the central spindle of a gearbox according to claim 1.

22. A bicycle having a frame to which front and rear wheels are attached, the rear wheel being driven from pedals mounted to the bicycle frame by means of a chain, the rear wheel of the bicycle being mounted to the bicycle frame by means of a single rear arm extending to one side of the rear wheel, and wherein the rear wheel is driven through a hub-mounted planetary gearbox having a substantially axisymmetrical outer casing mounted to the rear arm by means of a bearing positioned axially intermediate the length of the gearbox casing.

23. A bicycle according to claim 22, wherein the bearing is arranged substantially in the central plane of the rear wheel.

24. A bicycle according to claim 22 or claim 23 wherein the rear wheel is detachably mounted to the outer casing of the hub-mounted gearbox.

25. A bicycle according to any of claims 22 to 24 wherein the gearbox comprises a central spindle supporting a sun gear of said planetary gearbox, and the rear arm includes means for attaching one end of the central spindle to the rear arm coaxially with the bearing.

26. A bicycle substantially as herein described with reference to Figure 1, Figure 2 or Figure 3 of the accompanying drawings.

27. A hub-mountable planetary gearbox substantially as herein described with reference to Figures 3 to 5, Figure 6, Figure 7, Figure 8 or Figures 9 and 10 of the accompanying drawings.

28. A bicycle frame substantially as described herein with reference to Figure 1 or Figure 2 of the accompanying drawings.

ABSTRACT

BICYCLE HUB GEAR

There is described a hub-mountable planetary gearbox (17) for use in a bicycle (1) in which the rear wheel (3) is mounted on a single rear arm (13) positioned to one side of the rear wheel. The planetary gearbox comprises an outer casing (19) having an external bearing surface to engage a bearing mounted to the rear arm (13) of the bicycle. The rear wheel (3) of the bicycle may be detachably mounted to the outer casing (19) of the planetary gearbox (17). Alternatively, the outer casing of the gearbox may comprise integral flanges (20, 21) to which spokes (22) of a conventional bicycle wheel structure may be attached.

(FIGURE 3)

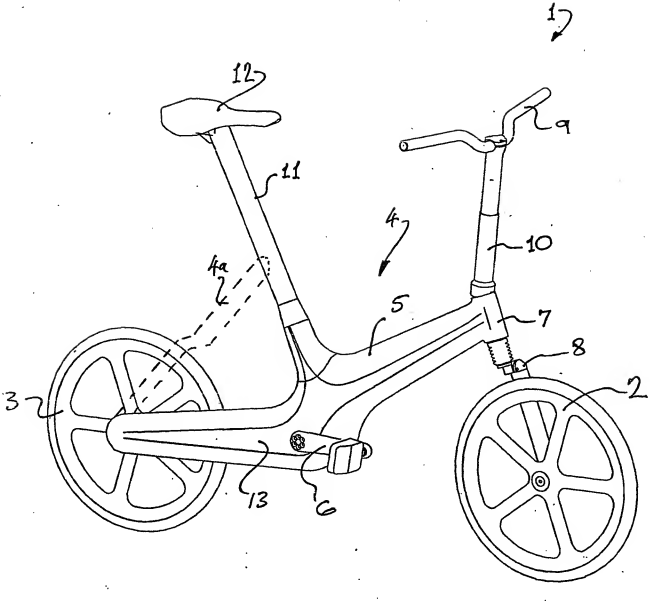

FIG 1

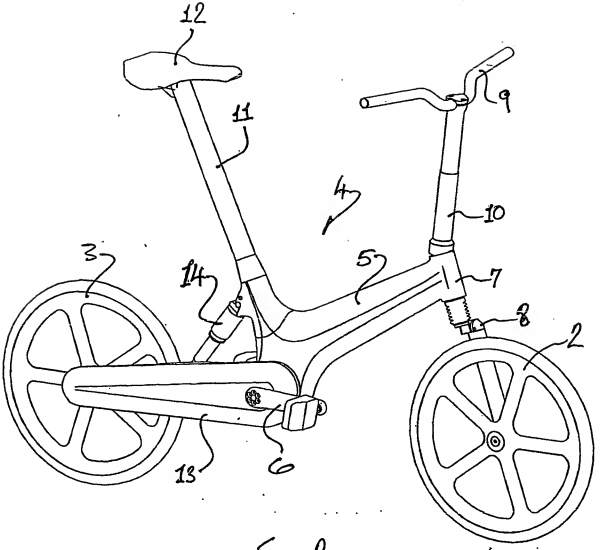

Fig 2

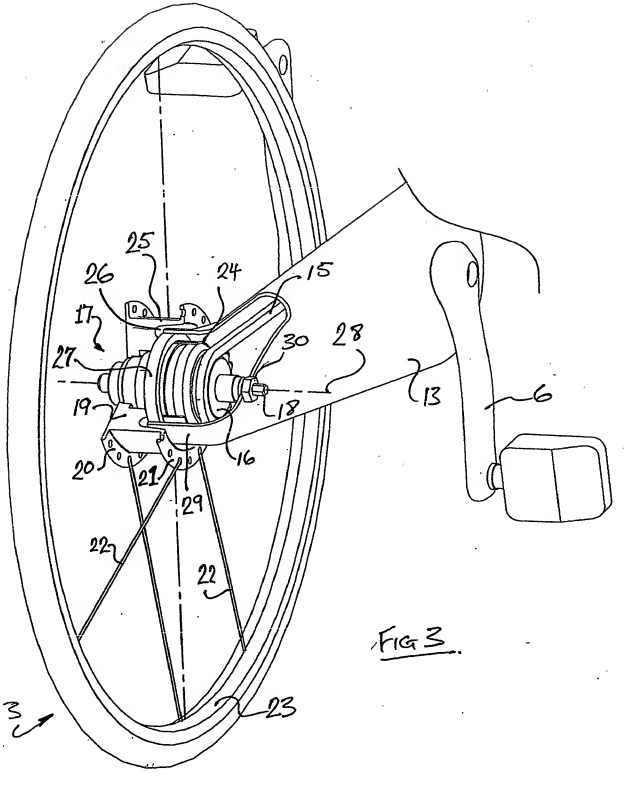

FIG 3

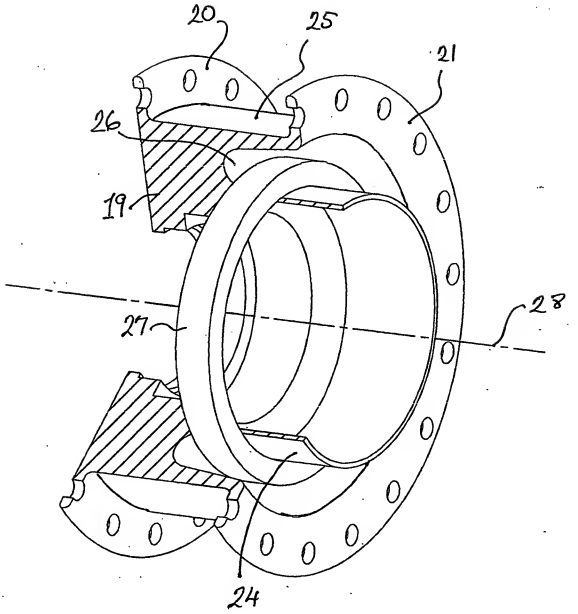

Fig 4

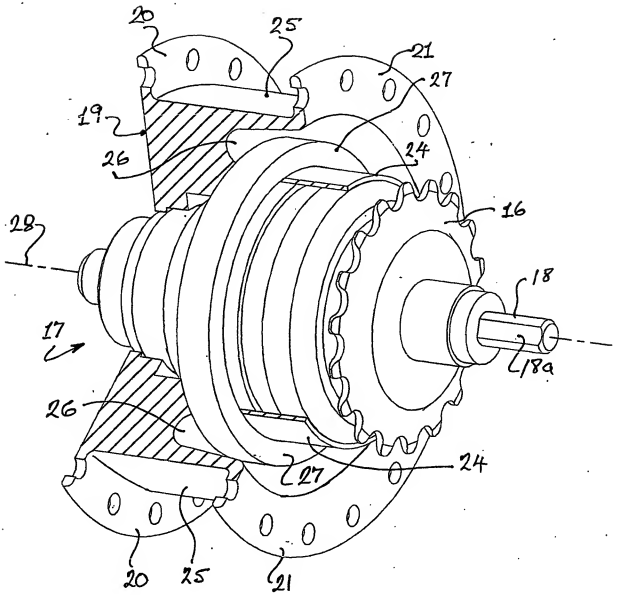

Fig 5

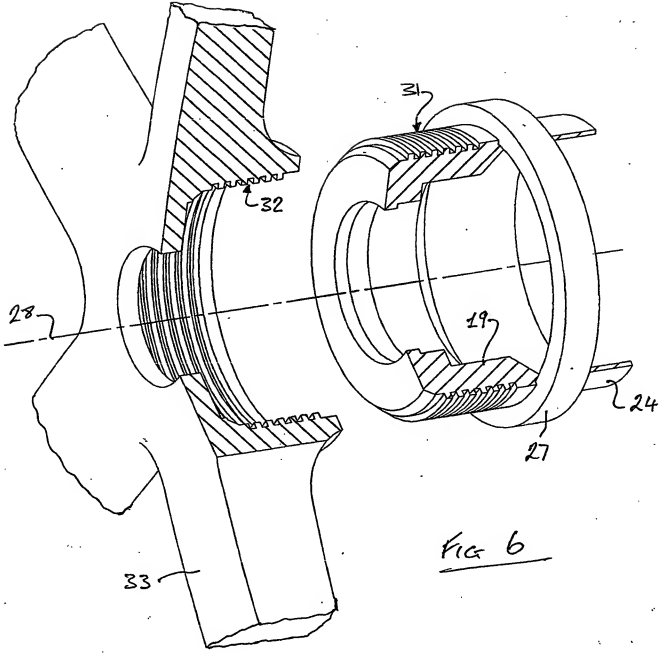

Fig 6

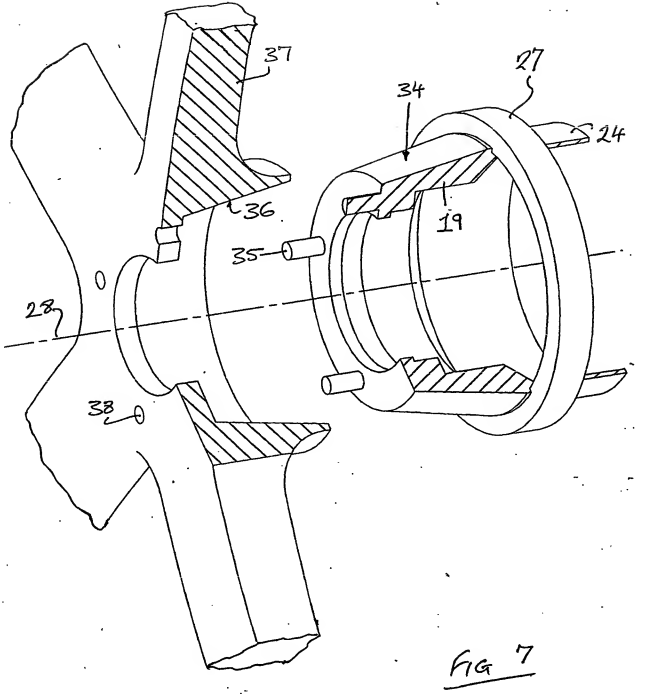

FIG 7

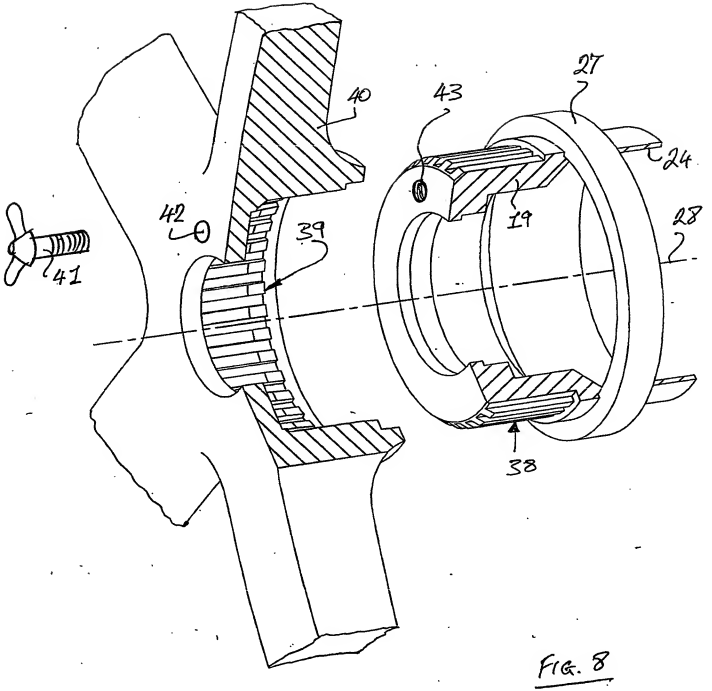

FIG. 8

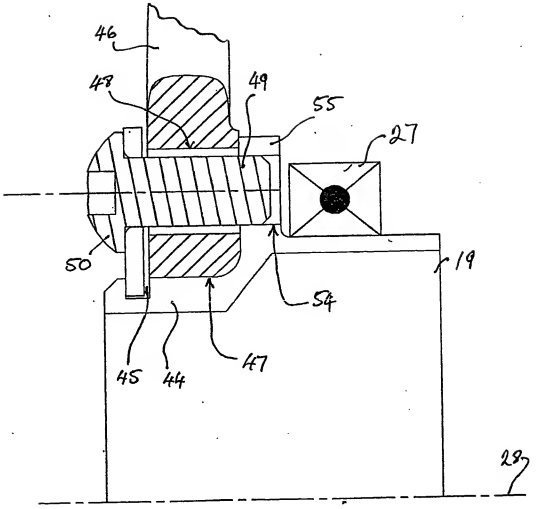

FIG. 9

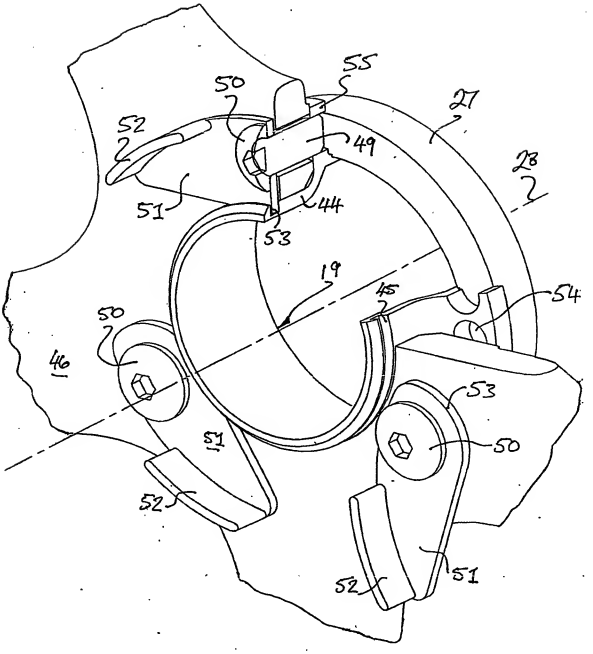

FIG. 10